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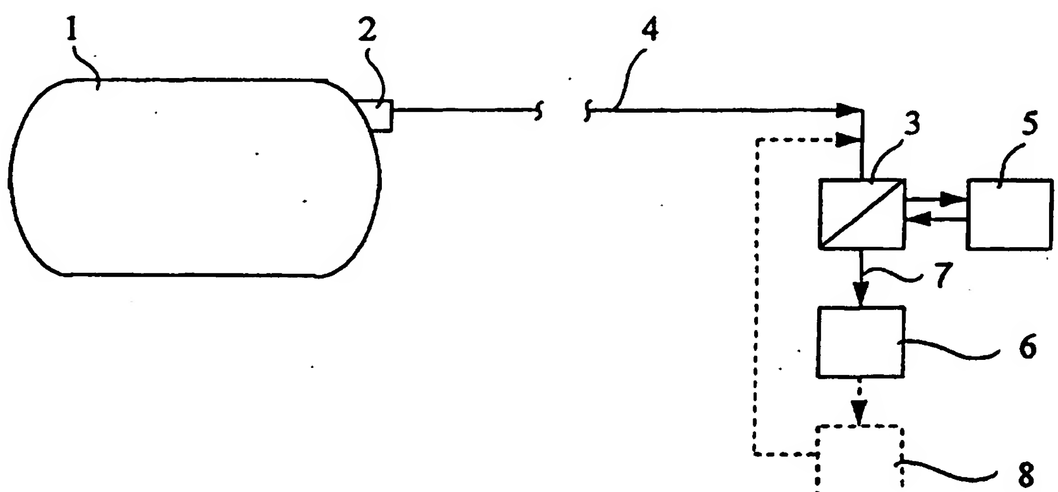

(57) Abstract

A system for cooling tools, workpieces or the like with liquefied gas, preferably carbon dioxide, which is delivered to the tool or to the workpiece in its liquid state. The liquefied gas is caused to vaporize as it comes into contact with the tool or the workpiece so as to effectively cool the same. The system includes an insulated tank (1) or a gas storage pressure vessel, means for vaporizing the liquefied gas either completely or partially prior to or during its transportation through conduit means (4) to a cooling unit (3, 5) which is located in the close proximity of the tool (6) or the workpiece and in which the gas is reliquefied. The liquefied gas is thus returned to the tool (6) or to the workpiece for cooling said tool or workpiece in conjunction with re-vaporization of the liquefied gas. The invention also relates to a method for use in cooling with liquefied gas.

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A METHOD AND APPARATUS FOR COOLING TOOLS, WORKPIECES OR THE LIKE USING LIQUEFIED GAS

The present invention relates to a method of cooling tools, workpieces or the like with liquefied gas, preferably CO_2, which is delivered to the tool or workpiece in a liquid state and then brought to a gaseous state as it comes into contact with the tool or workpiece, so as to effectively cool the same. The invention also relates to an arrangement for use in carrying out the method.

AGA AB markets under the trademark TOOLVAC a novel technique for injection moulding plastic products effectively. Tool mould inserts or parts of mould inserts are made of a gas-permeable microporous steel. In other respects, the material behaves in the manner of a typical tool steel. It can be machined, worked and polished to a desired surface finish.

The mould chamber can therewith be cooled by delivering liquefied carbon dioxide to the tool for instance, this liquid expanding in the micropores and vapourizing as heat is taken-up from surrounding material, therewith to achieve a very pronounced cooling effect throughout the whole of the mould. The cooling effect achieved is substantially more effective than that achievable with water, resulting in shorter cooling times and therewith in shorter product manufacturing cycle times.

The use of microporous material in the mould tool enables any air that may be present in the tool to be evacuated through the tool walls as the plastic material is injected into the mould. This eliminates the ventilation problems encountered with conventional tools and guarantees freedom from damage caused by enclosed pockets of air.

When applying the aforedescribed technique, it is necessary to ensure that the liquefied carbon dioxide does not vapourize

before reaching the microporous moulding tool. This requires the use of an effectively insulated conduit extending from a tank or pressure vessel that contains liquid carbon dioxide. Furthermore, it is necessary to maintain a high pressure in the conduit, therewith placing high demands on the valves used, among other things.

As the desired cooling effect requires only a small volume of carbon dioxide and the carbon dioxide is normally delivered intermittently at short intervals, it is necessary to take a larger and more uniform flow from the tank than that actually required, so as to maintain the cold temperature required to keep the carbon dioxide in a liquid state, wherein it is necessary to pump the major part of this larger volume back to the tank via a circuit which includes an expensive cooling unit.

One problem that can arise is that foreign substances present in liquid carbon dioxide, such as oil, contaminate the tool and block the pores therein.

The prime object of the present invention is to provide an improved cooling method which utilizes liquefied gas, preferably CO_2, and with which the aforesaid disadvantages are eliminated, among other things.

The invention is based on the realization that this object can be achieved by first allowing the gas stored in a liquid state to vapourize prior to or during its transportation to the tool, and then re-liquefying the gas prior to its use in cooling the tool.

In this regard, a method defined in the first paragraph is particularly characterized in that the gas is stored in a liquefied state in an insulated tank or in a pressure vessel, in that the liquid gas is vapourized completely or partially and conducted through conduit means to a cooling unit placed

in the near vicinity of the tool or the workpiece; in that the gas is re-liquefied in the cooling unit; and in that the liquefied gas is delivered to the tool or the workpiece so as to cool the same in conjunction with said re-vapourization of the liquefied gas.

When the liquefied gas stored in the tank or the pressure vessel is vapourized, any oil that is present will be separated out, therewith eliminating the risk of oil being delivered to the tool. The re-vapourized coolant can also be readily transported to the tool in simple, non-insulated conduits with the aid of relatively inexpensive valves because of a low system pressure. Tank installations are also simpler and less expensive, since pumps and insulated return conduits can be excluded, among other things. The cooling unit connected to the tank can also be excluded.

In order to prevent re-contamination of the gas as it is liquefied in the cooling unit adjacent the tool, the process of condensation is suitably effected in a heat exchanger connected to a cooling machine.

A very environmentally friendly cooling technique can be achieved by collecting at least a part of the liquefied gas that is vapourized upon contact with the tool and returning said gas to the cooling unit for re-newed liquefication and re-use. This reduces gas consumption.

The aforedescribed method can be applied advantageously for cooling a plastic injecting moulding tool which includes inserts manufactured from a microporous material, such as microporous steel, wherein the gas is preferably CO_2.

Other characteristic features of the method and of an arrangement for use when carrying out the method will be evident from the following Claims.

The invention will now be described in more detail with reference to the enclosed drawing which illustrates diagrammatically a system according to the invention.

The reference numeral 1 in the drawing identifies a preferably vacuum-insulated tank containing liquefied carbon dioxide. The tank also contains gaseous carbon dioxide, which lies above the level of liquid in the tank. The tank pressure may be in the order of 20 bars and the temperature in the order of about -20°C. The reference numeral 2 identifies a carbon dioxide outlet. If so desired, the outlet may be connected to an evaporator connected to the tank 1 and supplied with liquid carbon dioxide from the tank. A conduit 4 connects the outlet 2 to a condenser 3 in the form of a heat exchanger. Alternatively, the conduit 4 may be dimensioned to enable it to be supplied with liquid carbon dioxide from the tank 1, wherewith the liquid carbon dioxide vapourizes during its passage through the conduit to the heat exchanger 3. The tank outlet may alternatively be positioned to obtain gaseous carbon dioxide directly therefrom.

The heat exchanger 3 is connected to a cooling machine 5 which may be of any conventional design and which enables the carbon dioxide to be cooled and liquefied in the heat exchanger 3, so that supercooled, liquid carbon dioxide can be delivered to a tool 6, for instance to an injection moulding tool made of microporous steel. The heat exchanger 3 is located close to the tool 6, to ensure that carbon dioxide will be delivered to the tool in a liquid state. This liquid carbon dioxide expands in the pores in the tool and vapourizes while taking-up heat and therewith cooling adjacent parts, *inter alia* the moulding present in the mould chamber.

The use of injection moulding tools that are made of microporous steel is known to the art and will not be described in detail in this document. Those wishing to learn the function of such tools are referred to Swedish Patent Specifications SE-

C-454247 and SE-C-466951.

A system constructed in accordance with the aforegoing is a very simple system, among other things because non-insulated conduits can be used and because necessary valves will only operate at relatively low pressures. Furthermore, no pump is required and no tank return circuit, and neither does the system require the provision of a costly cooling unit for liquefying recycled carbon dioxide.

Any contaminants, such as oil, present in the liquid carbon dioxide in the tank 1 will be separated-out as the carbon dioxide evaporates. In this regard, an oil trap or some similar device for collecting contaminants separated from the gas may be provided. The tank must be washed clean at regular intervals when evaporation of the carbon dioxide takes place in the tank. The gaseous carbon dioxide in the conduit 4 will thus be essentially free from contaminants, and consequently it is preferred that liquefaction of the gas is effected in a heat exchanger or the like, so as to avoid contamination of the gas by fresh contaminants. However, the heat exchanger 3 may be replaced with some equivalent device that is capable of cooling the gas without contaminating the same. The tank 1 may also be replaced with a gas bottle or a pack of bottles or some other pressure vessels that contain liquid carbon dioxide under high pressure, e.g. a pressure in the magnitude of 50-60 bars. In this regard, an evaporator is conveniently connected to the gas outlet.

In addition to cooling a microporous moulding tool, the liquefied gas can be used to cool other types of tools or workpieces, e.g. cutting tools, or may be used in other types of processes that require the use of liquefied gas. It will be understood that cryogenic gases other than carbon dioxide can be used when so desired.

Because the vapourized coolant can be collected subsequent to

cooling the tool, as indicated by block 8, and returned to the condenser 3 located close to the tool 4 for re-newed liquefaction and re-use, there is obtained a very environmentally friendly cooling process.

It can be said in summary that vapourization of the coolant prior to its transport to the tool, and liquefaction of the vaporized coolant in equipment located close to the tool afford three important advantages, namely that the gas is cleansed from contaminants, such as oil among others, that simpler and less expensive equipment can be used, and that an environmentally friendly cooling process can be achieved.

CLAIMS

1. A method of cooling tools, workpieces or the like with liquefied gas, preferably CO_2, which is delivered to the tool or to the workpiece in a liquid state and caused to vapourize as it comes into contact with the tool or the workpiece so as to effectively cool the same, **characterized** by storing the gas in a liquefied state in an insulated tank or in a pressure vessel, vapourizing the liquefied gas either totally or partially and transporting the liquefied gas through a conduit to a cooling unit located in the close proximity of the tool or the workpiece, liquefying the gas in the cooling unit, and delivering the liquefied gas to the tool or to the workpiece for cooling of said tool or workpiece as the liquefied gas re-vapourizes.

2. A method according to Claim 1, **characterized** by liquefying the gas in a heat exchanger connected to a cooling machine.

3. A method according to Claim 1 or 2, **characterized** by collecting at least a part of the liquefied gas that vapourizes upon contact with the tool or the workpiece and returning this collected quantity to the cooling unit for re-newed liquefaction and re-use.

4. A method according to any one of Claims 1-3, **characterized** by applying the method to cool an injection moulding tool, e.g. a plastic injection moulding tool, which includes inserts that are made of a microporous material, such as microporous steel, wherein the gas used is carbon dioxide.

5. A method according to any one of Claims 1-4, **characterized** by separating contaminants, such as oil, present in the liquefied gas in conjunction with vapourization of the liquefied gas taken from the tank or the pressure vessel, said contaminants being

collected and removed.

6. A system for cooling tools, workpieces or the like with liquefied gas, preferably carbon dioxide, which is delivered to the tool or to the workpiece in its liquid state and caused to vapourize as it comes into contact with said tool or said workpiece so as to effectively cool the same, **characterized** in that the system includes an insulated tank (1) or a gas storage pressure vessel, means for vapourizing the liquefied gas either completely or partially, conduit means (4) for transporting the at least partially vapourized liquefied gas to a cooling unit (3, 4) located in the close proximity of the tool (6) or the workpiece and in which the gas is re-liquefied, and means (7) for delivering the liquefied gas to the tool (6) or to the workpiece for cooling said tool or workpiece in conjunction with re-vapourization of the liquefied gas.

7. A system according to Claim 6, **characterized** in that the cooling unit includes a heat exchanger (3) connected to a cooling machine (5).

8. A system according to Claim 6 or 7, **characterized** by means (8) for collecting at least a part of the gas that evolves from vapourization of the liquefied gas in contact with the tool (6) or the workpiece and for returning this collected gas to the cooling unit (3, 5) for re-newed liquefaction and re-use.

9. A system according to any one of Claims 6-8, **characterized** in that the tool (6) is an injection moulding tool, e.g. a plastic injection moulding tool, which includes inserts made of a microporous material, such as a microporous steel, wherein the gas is carbon dioxide.

10. A system according to any one of Claims 6-9, **characterized**

by means for collecting contaminants, such as oil, present in the liquefied gas and separated-out upon vapourization of the liquefied gas taken from the tank (1) or the pressure vessel.

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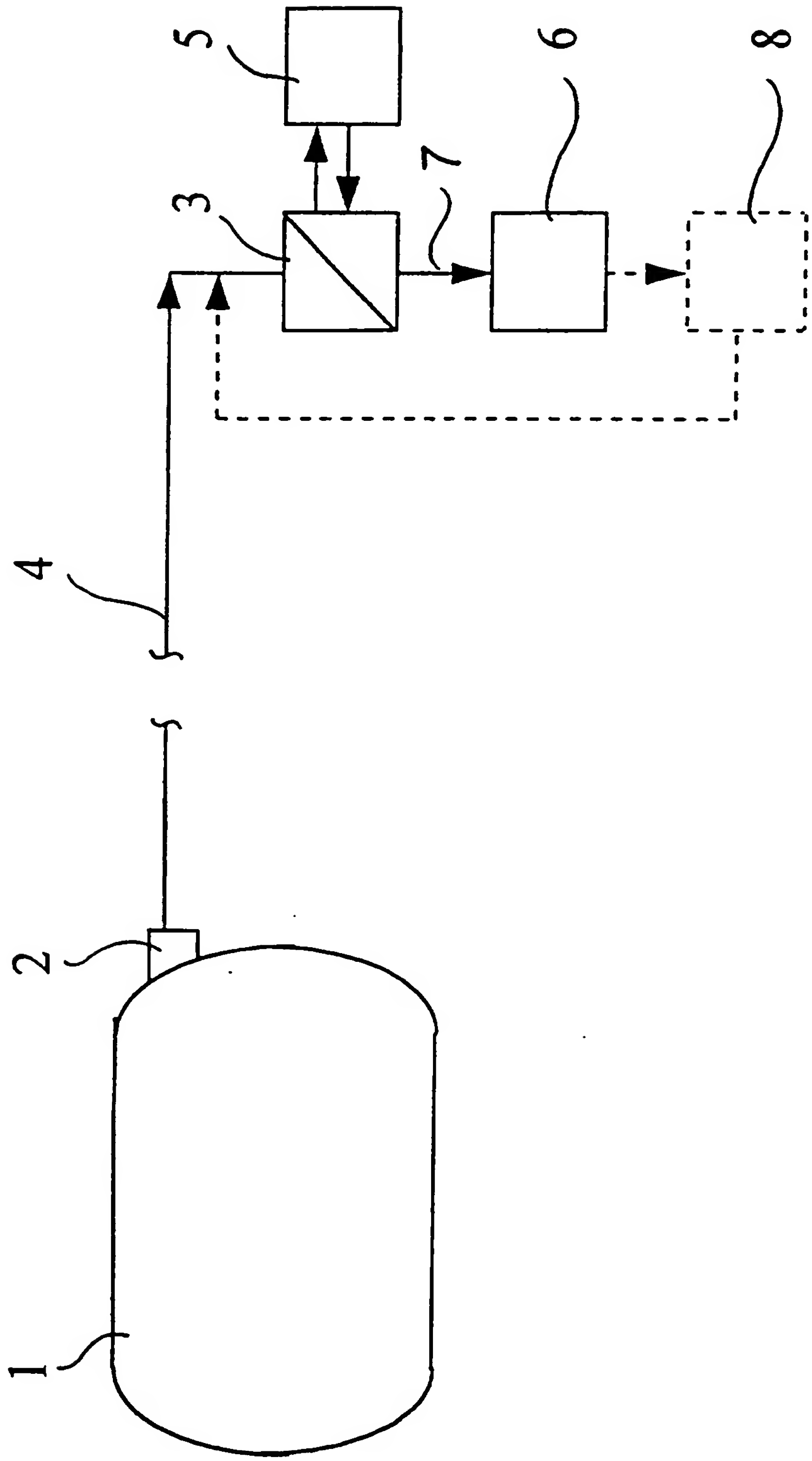

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 96/01364

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: B23Q 11/10, B29C 33/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: B23Q, B29C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0369442 A2 (TOOLVAC ENGINEERING AB), 23 May 1990 (23.05.90), abstract --	1-10
A	WO 921543 A1 (TOOLVAC ENGINEERING AB), 17 Sept 1992 (17.09.92), abstract --	1-10
A	US 3661483 A (BOSE), 9 May 1972 (09.05.72), figure 1, abstract --	1-10
A	Patent Abstracts of Japan,, abstract of JP,A, 62-27132 (IWATANI & CO), 5 February 1987 (05.02.87) --	1-10

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	AT 378933 B (ALPENLÄNDISCHE INDUSTRIEGAS- & TEXTILCHEMIE-WERKE KG), 25 October 1985 (25.10.85) --	1-10
A	EP 0252312 A2 (MESSER GRIESHEIM GMBH), 13 January 1988 (13.01.88), figure 2, abstract -- --------	1-10

INTERNATIONAL SEARCH REPORT
Information on patent family members

28/10/96

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A2- 0369442	23/05/90	SE-T3- 0369442	
		AT-T- 123685	15/06/95
		DE-D,T- 68923060	30/11/95
		ES-T- 2075842	16/10/95
		JP-A- 2243308	27/09/90
		SE-B,C- 462525	09/07/90
		SE-B,C- 466950	04/05/92
		SE-A- 8804129	16/11/88
		SE-A- 8804644	23/12/88
		US-A- 5021203	04/06/91
WO-A1- 921543	17/09/92	NONE	
US-A- 3661483	09/05/72	US-A- 3760599	25/09/73
AT-B- 378933	25/10/85	NONE	
EP-A2- 0252312	13/01/88	DE-A- 3623420	14/01/88
		JP-A- 63022246	29/01/88
		US-A- 4768356	06/09/88